NASA LaRC Contribution to the High Angle Working Group of the Third Aeroelastic Prediction Workshop: BSCW Transonic Flutter

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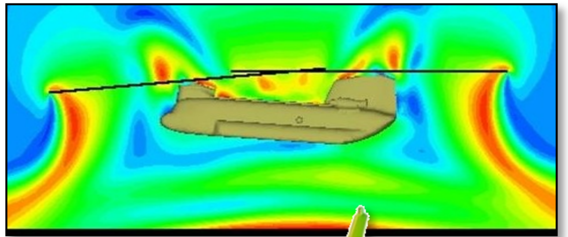
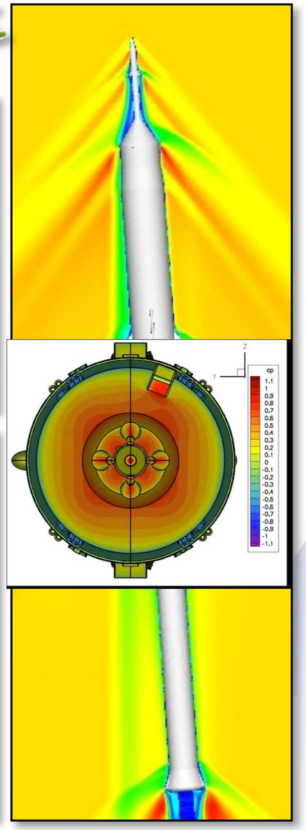
FUN3D Core Capabilities

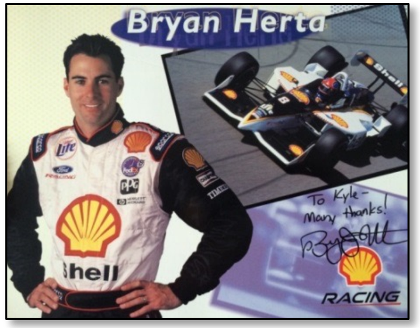
http://fun3d.larc.nasa.gov/

- Established as a research code in late 1980s; now supports numerous internal and external efforts across the speed range
- Solves 2D/3D steady and unsteady Euler and RANS equations on node-based mixed element grids for compressible and incompressible flows
- General dynamic mesh capability: any combination of rigid / overset / morphing grids, including 6-DOF effects
- Aeroelastic modeling using mode shapes, full FEM, etc.
- Constrained / multipoint adjoint-based design and mesh adaptation
- Distributed development team using agile/extreme software practices including 24/7 regression, performance testing
- Capabilities fully integrated, online documentation, training videos, tutorials

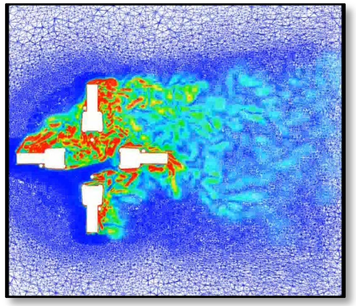


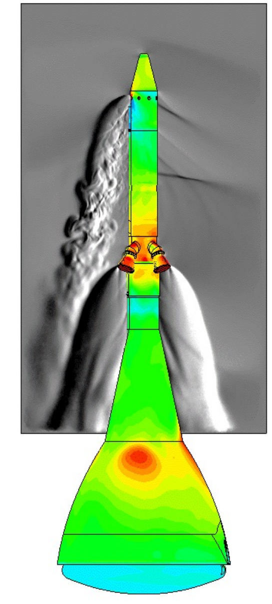
US Army

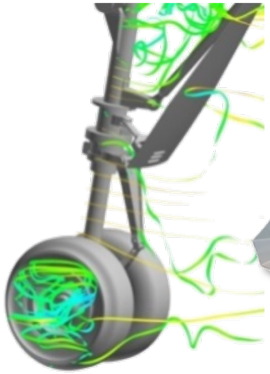


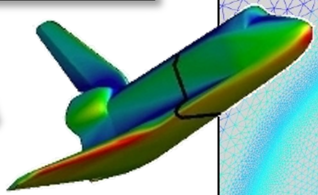


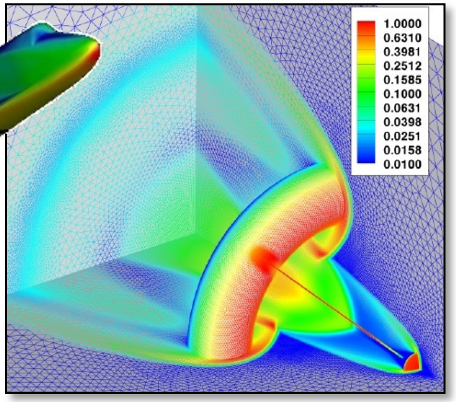
Georgia Tech











BSCW Flutter Analysis at Mach 0.8

Time-Domain Analysis

- Unforced-wing **steady state** solution
- **Static aeroelastic solution:** coupled unsteady solution with large structural damping ratio value
- **Dynamic aeroelastic solution** (flutter): coupled unsteady solution with small structural damping value and initial **‘kick’**
- Analyses are repeated at **many *q* values** to find stable and unstable wing response
- Matrix-pencil method is used to compute **damping values** from the modal response
- Dynamic pressure at **‘zero’ damping is flutter** dynamic pressure
- SA, QCRRC, DDES
- Roe scheme, Venkatakrishnan, Hvanalbada limiters, Second order in time

https://fun3d.larc.nasa.gov
Kiviaho, et al., “Flutter Boundary Identification from Time-Domain Simulations Using the Matrix Pencil Method,” https://doi.org/10.2514/1.J058072

Linearized Frequency Domain (LFD) w/Mesh Adaptation (and Fixed Mesh)

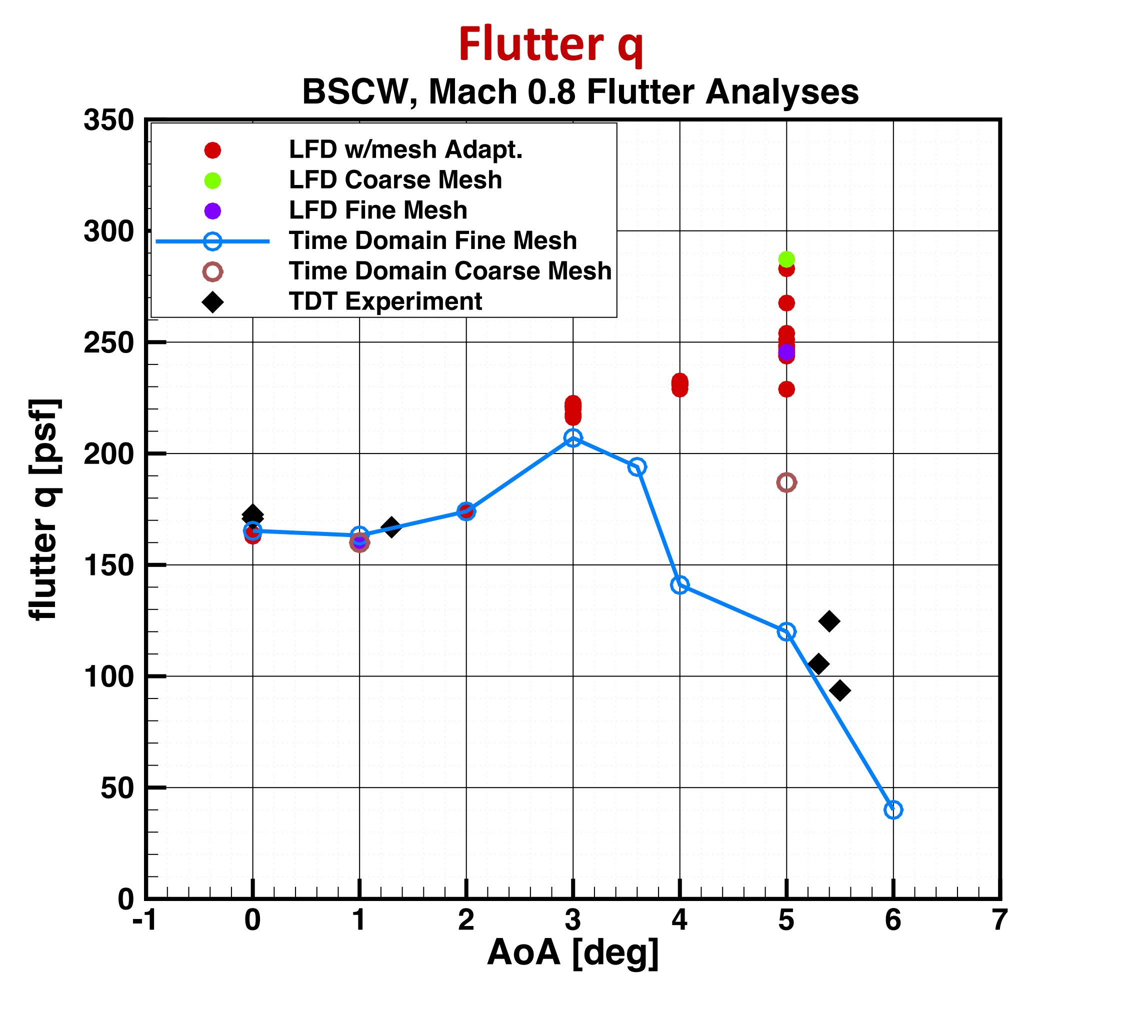
- Unforced-wing **steady state** solution using FUN3D/SFE at a given AoA and BSCW mesh
- **LFD equations** are solved where aerodynamic response to **harmonic motion of structural modes** linearized about the steady state solution is computed
- Resulting **GAFs** are processed through a p-k solver to compute **flutter-*q***
- ***Refine*** is used to create a new mesh with its adaptation mechanics
- AoA is updated based on pitch rotation needed to bring the system into pitch equilibrium
- Process is repeated with new AoA and new mesh

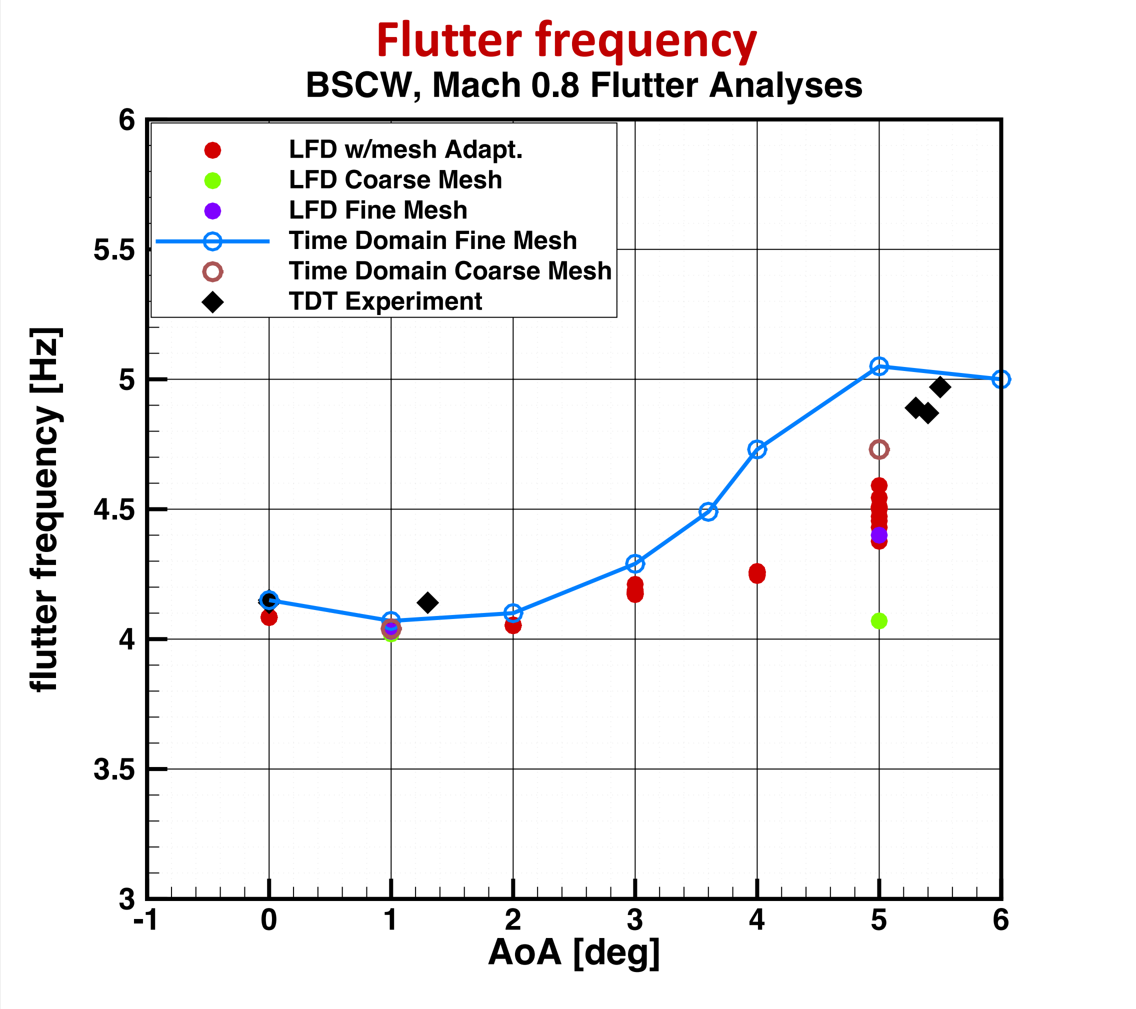
Stanford, et al., “Ongoing Aeroelastic Prediction and Validation Activities at NASA Langley Research Center, AIAA Paper, TBD.
Jacobson, et al., “Flutter Analysis with Stabilized Finite Elements based on the Linearized Frequency-domain Approach,” AIAA Paper 2020-0403

BSCW Flutter Analysis at Mach 0.8

SciTech 2022 Publication: https://doi.org/10.2514/6.2022-1347

Time-Domain Analysis (Fixed Mesh) + LFD w/Mesh Adaptation and Fixed Mesh





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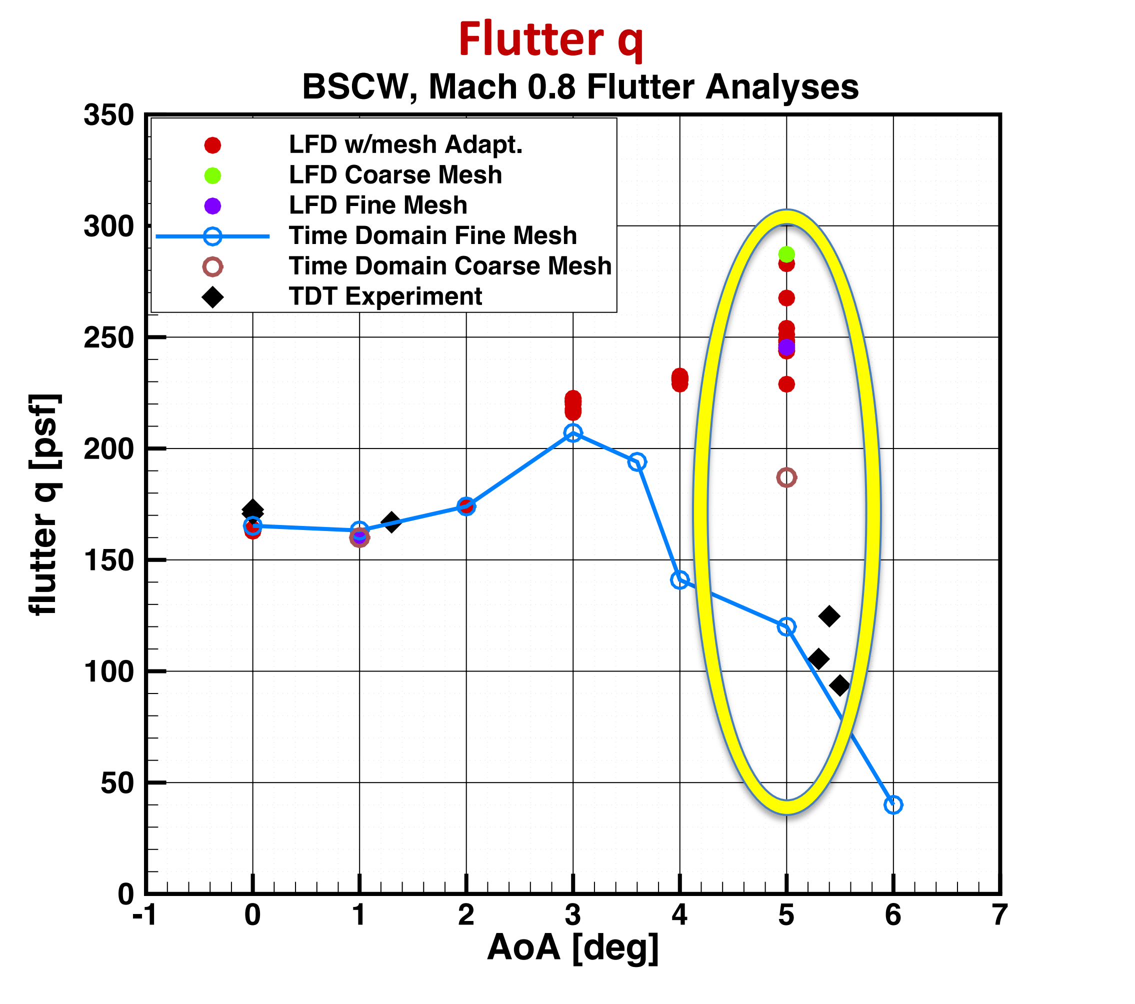
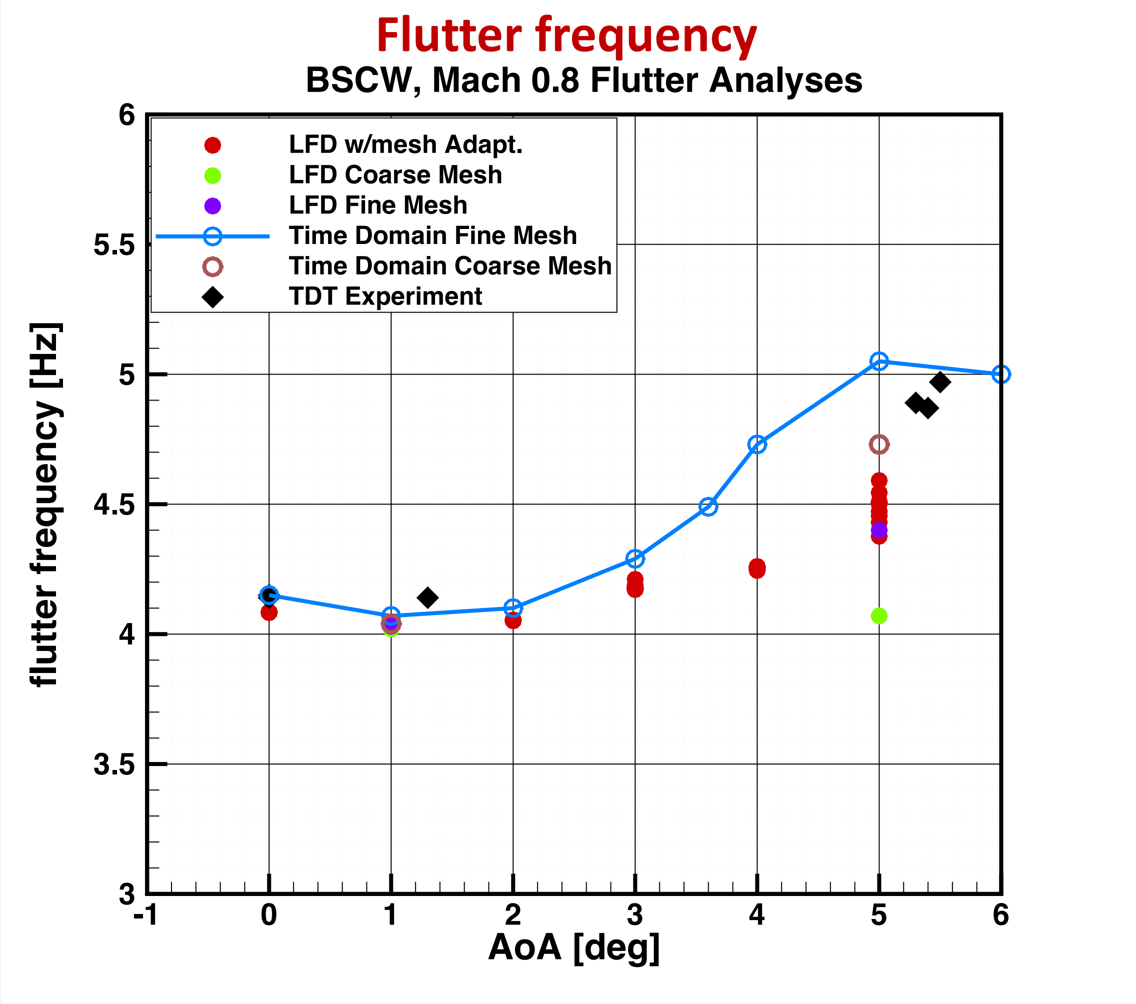
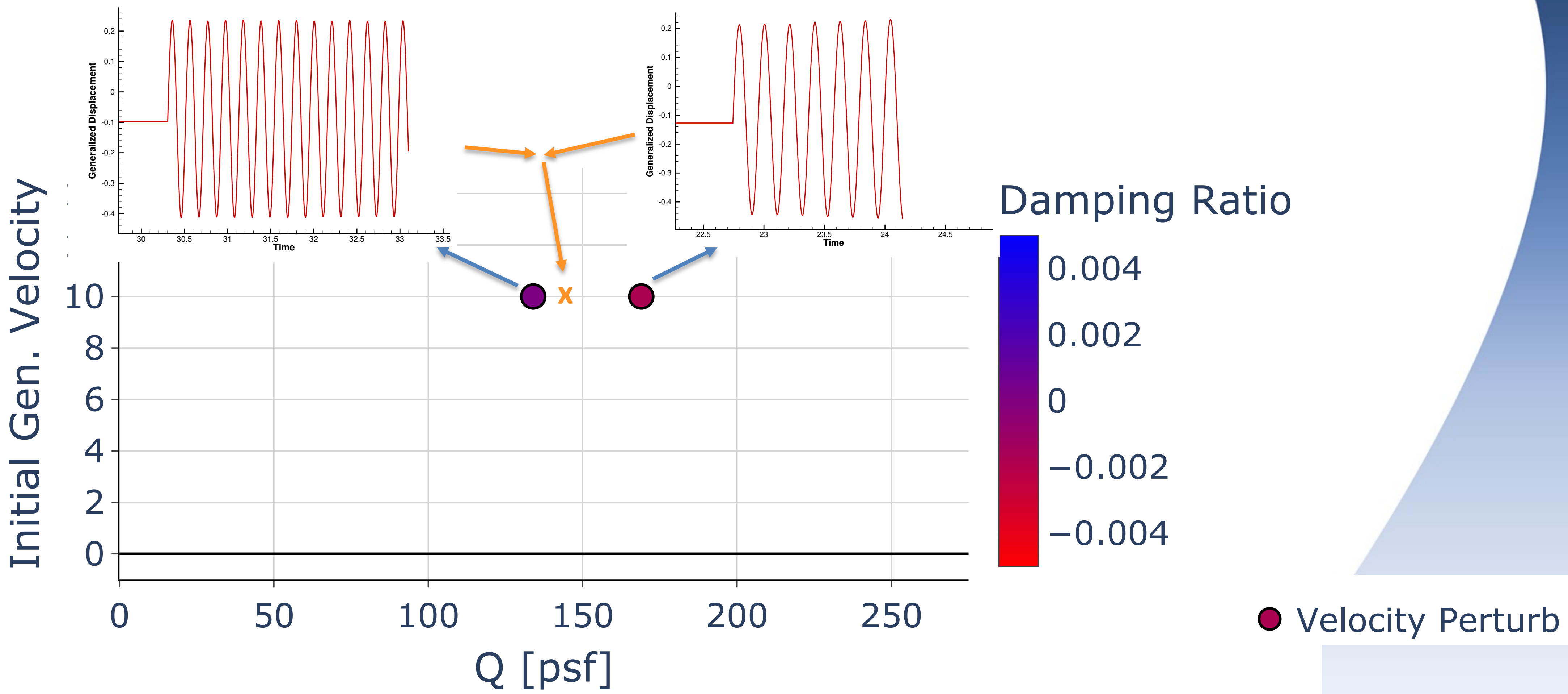




BSCW Flutter Analysis at Mach 0.8

Time Domain Kick Size, gvel = 10

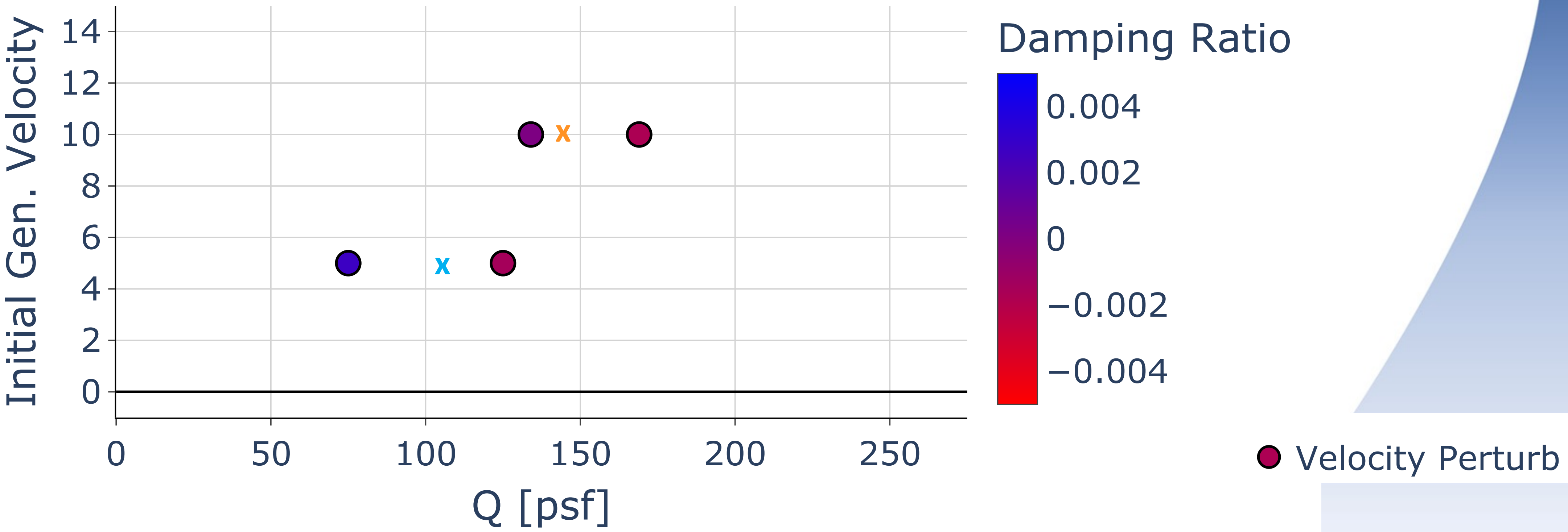
Interpolated Flutter Q = 140 psf



BSCW Flutter Analysis at Mach 0.8

Time Domain Kick Size, gvel = 5

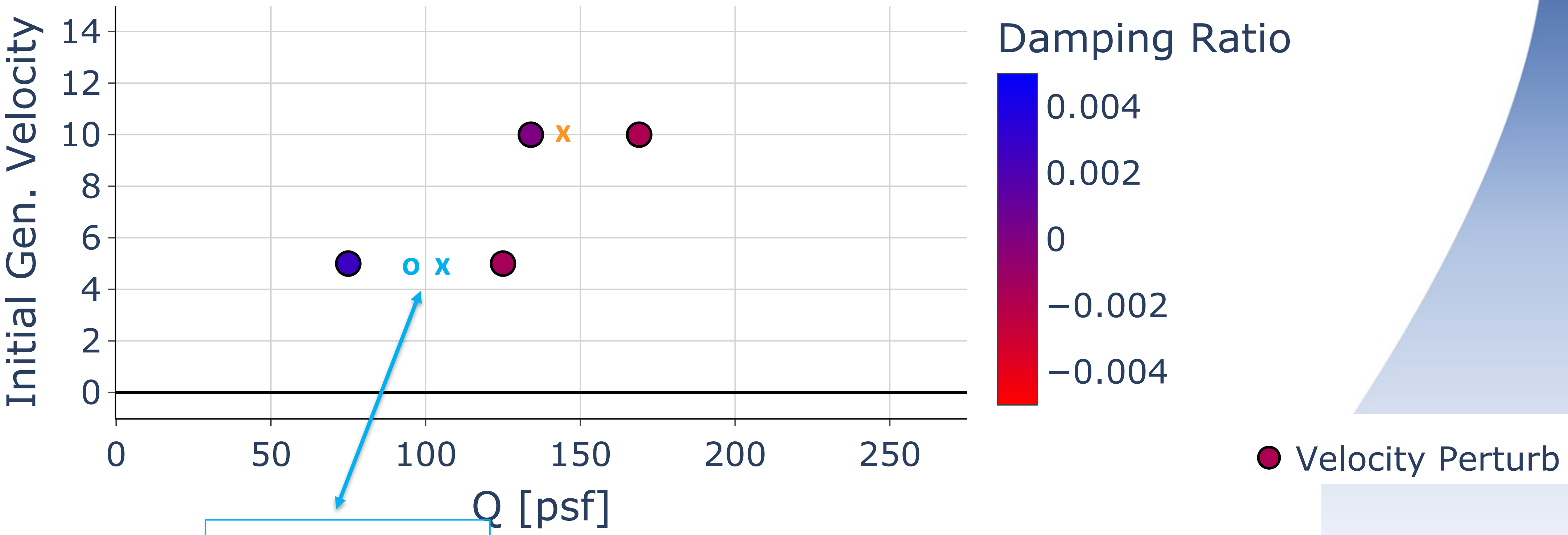
Interpolated Flutter Q = 120 psf



BSCW Flutter Analysis at Mach 0.8

Time Domain Kick Size, gvel = 5

Interpolated Flutter Q = 120 psf



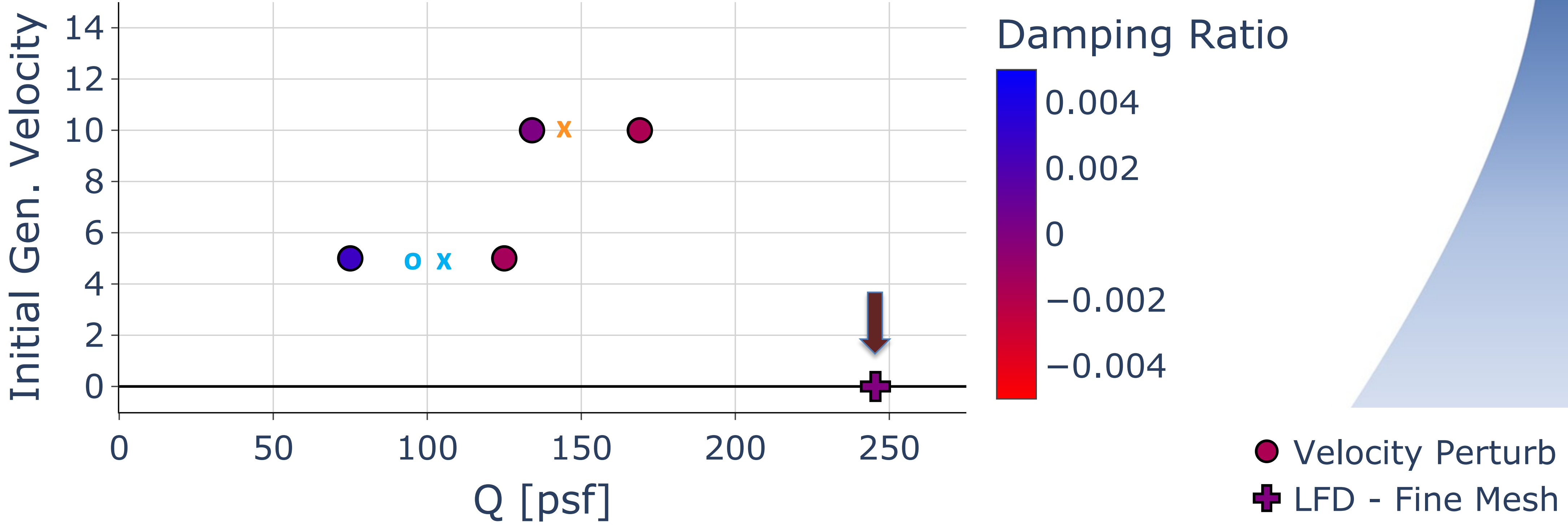
x - SA
o - SA QCR RC

QCR – Quadratic Constitutive Relationship 2000 version
RC – Rotation / Curvature Correction

BSCW Flutter Analysis at Mach 0.8

Linearized Frequency Domain

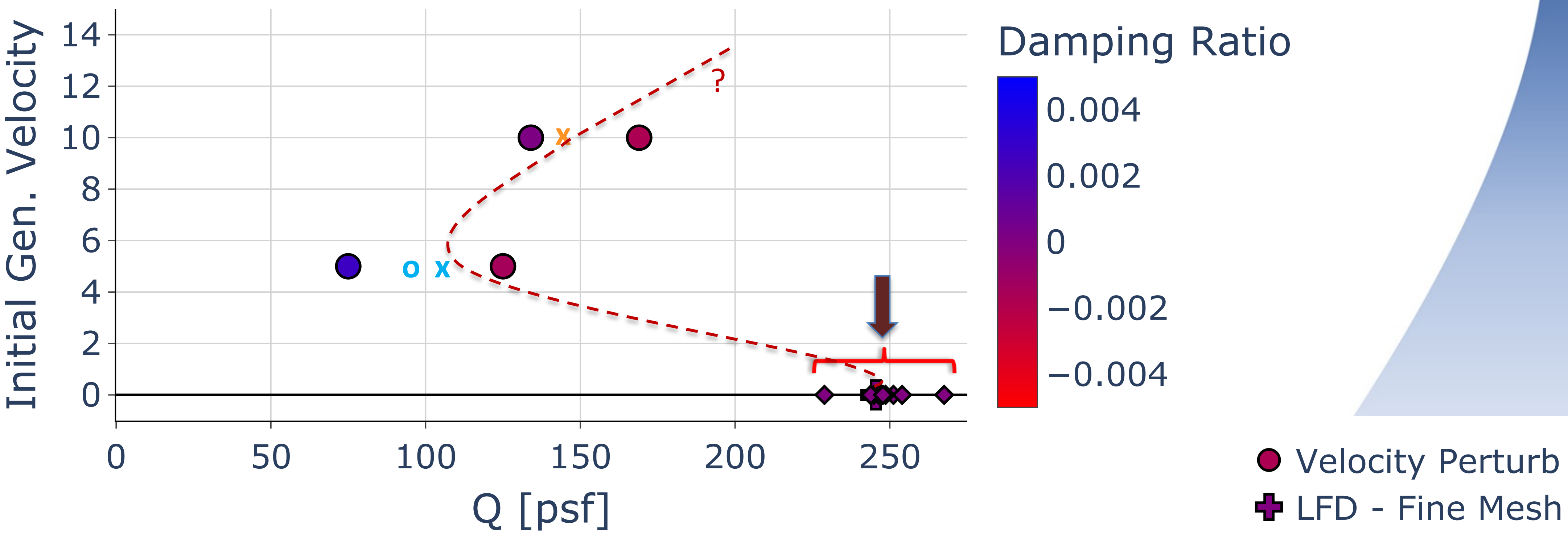
Fixed Mesh Solution Flutter **Q = 240 psf**



BSCW Flutter Analysis at Mach 0.8

Linearized Frequency Domain

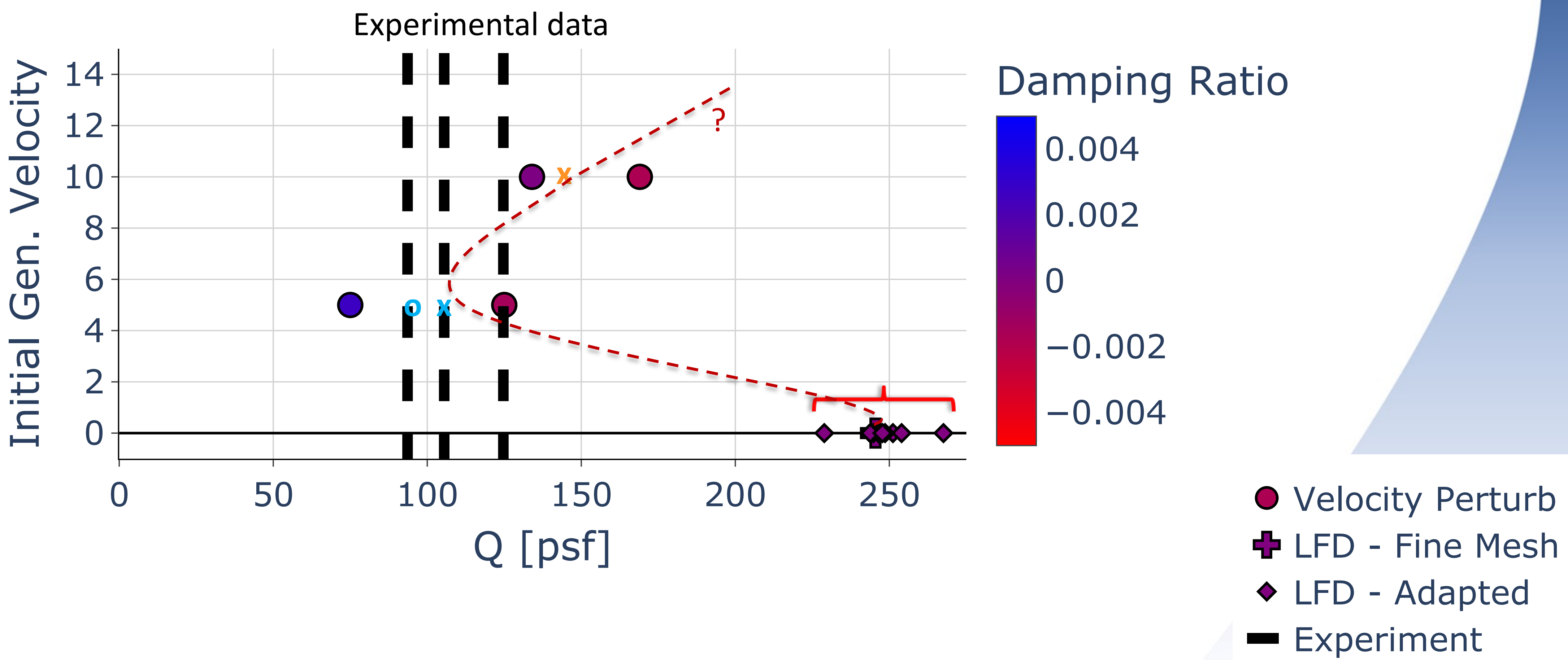
Adapted Mesh Flutter **Q = 230 - 270 psf**



BSCW Flutter Analysis at Mach 0.8

Linearized Frequency Domain

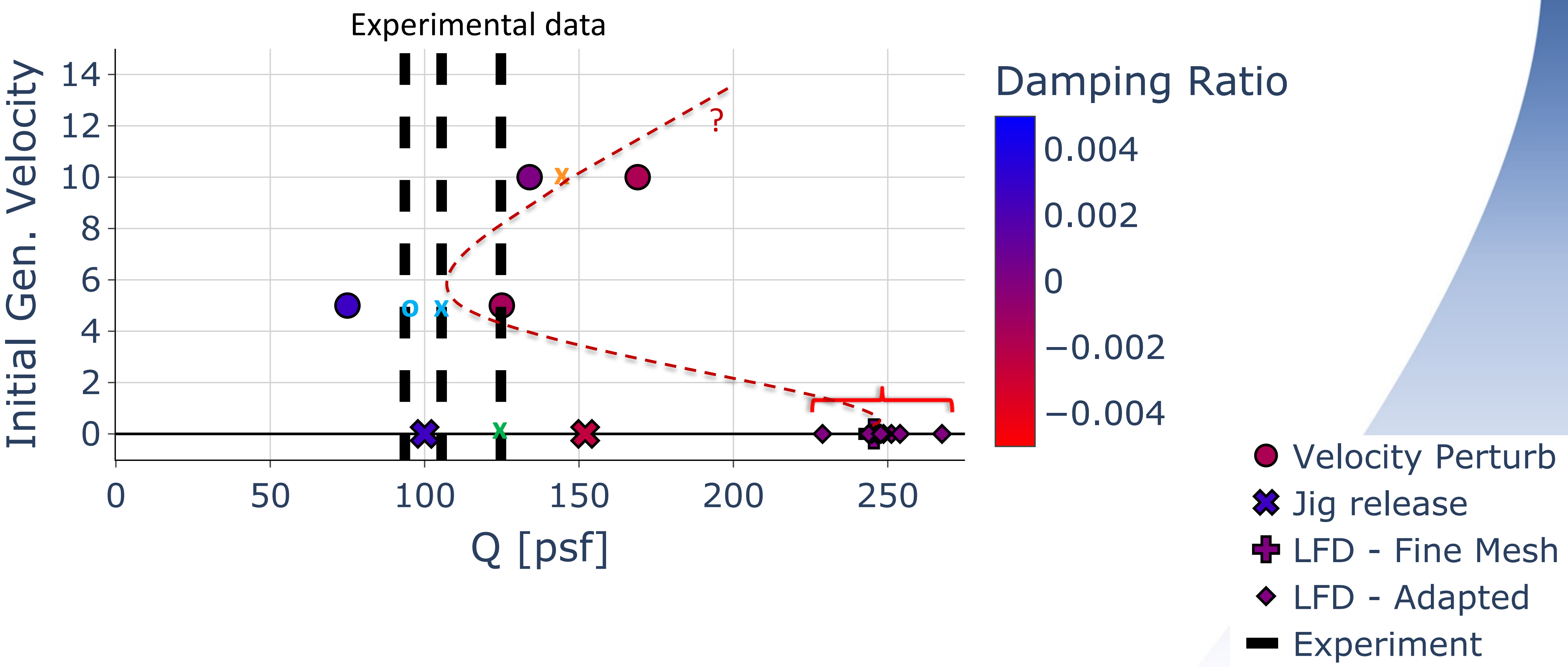
Adapted Mesh Flutter **Q = 230 - 270 psf**



BSCW Flutter Analysis at Mach 0.8

Time Domain

Fixed Mesh Jig Release Flutter **Q = 125 psf**

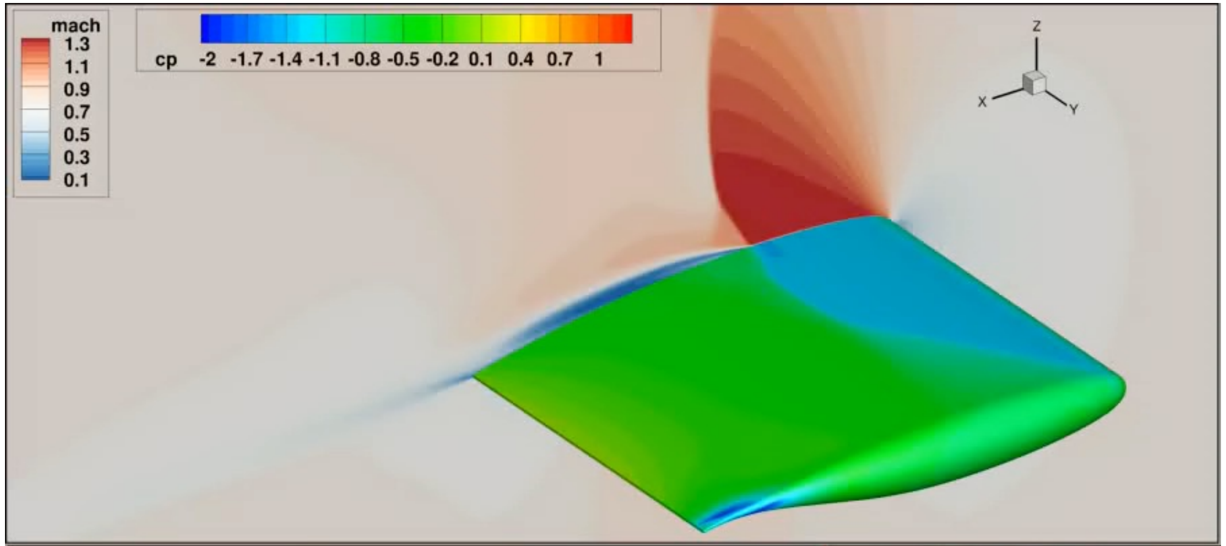


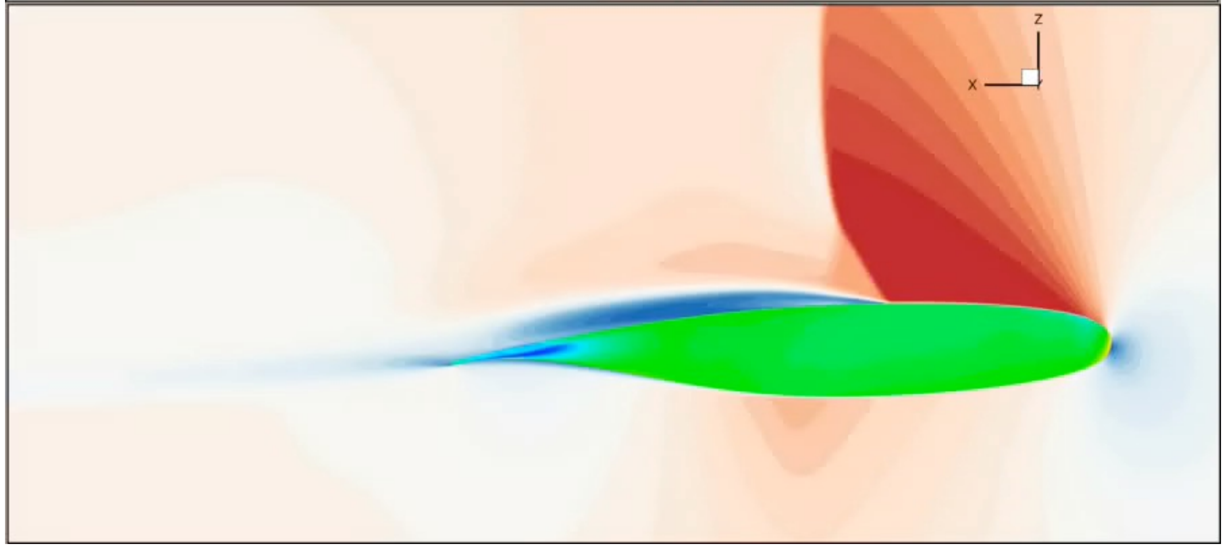
BSCW Flutter Analysis at Mach 0.8

Time Domain Jig Release

DDES Solution Flutter Q ~ 125 psf

Animation





BSCW Flutter Analysis at Mach 0.8
Conclusions

- Wide range of flutter dynamic pressure predictions
  - Is it due to the mixed attached / separated flow and URANS application?
- Big surprise: effect of Limiter and no/Limiter on flutter prediction
- More experimental data is needed !!!